U.S. DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

MERCED RIVER
INSTREAM FLOW STUDY
YOSEMITE NATIONAL PARK

FINAL REPORT

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Prepared
by

Gary L. Taylor
Division of Ecological Services
Sacramento, California

For

National Park Service

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SUMMARY

This report contains the final results of a 14-month instream flow study completed in October 1983. The study provides planning information for the National Park Service (NPS) by assessing impacts of water withdrawals on fishery and other recreational resources of the Merced River.

The flow study utilized methodologies developed by the Fish and Wildlife Service's Cooperative Instream Flow Service Group to predict changes in the amount of fish habitat and aquatic recreational area resulting from incremental changes in river flow. Data on fish species was obtained by electrofishing within the study area. The habitat available to rainbow trout during specific life stages (adult, spawning, fry and juvenile) was determined for flows ranging from 1 to 600 cubic feet per second for the Happy Isles and Leydig Meadow study reaches.

At the request of the NPS, we focused our analysis on 1-3 cfs water withdrawal impacts during critical periods. This range of flow withdrawal is being considered in planning for a new water treatment system for Yosemite Valley.

The results of this study indicate that water withdrawals of 3 cfs could significantly impair juvenile rainbow trout habitat in the Happy Isles reach when river flow is 20 cfs or less. Without tributary inflow to offset a 3 cfs withdrawal, juvenile rainbow trout habitat would be significantly impaired in the Leydig Meadow reach at flows of 36 cfs or less.

Since normal year median monthly flows in September, October and November at Happy Isles are near 20 cfs, an alternate water supply would be required to prevent fishery losses during this period. Normal year median monthly flows in the Leydig Meadow reach during September and October are near 36 cfs. Flow reductions of 3 cfs during these months would cause significant reduction in juvenile habitat. Therefore, an alternative water supply should be available during September and October to insure that flow needs for the fishery are met.

Water temperatures in the Happy Isles reach are less than ideal in some months for trout production. Dissolved oxygen levels are near the ideal in all months of the year in the Happy Isles reach. A cursory review of several other water quality parameters indicates that conditions are generally suitable for trout production. There was no available data on water temperature, dissolved oxygen or other water quality index for the Leydig Meadow reach.

As with most rivers, the Merced is a dynamic system constantly undergoing change. Sometimes these changes are subtle and difficult to observe, but at other times the changes are dramatic, such as those that resulted from the fall 1982 flooding in Yosemite Valley. Major changes affect the overall fishery habitat and require periodic reevaluation of flow requirements. Therefore, the findings of this flow study should be considered as interim guidelines for fishery management.

INTRODUCTION

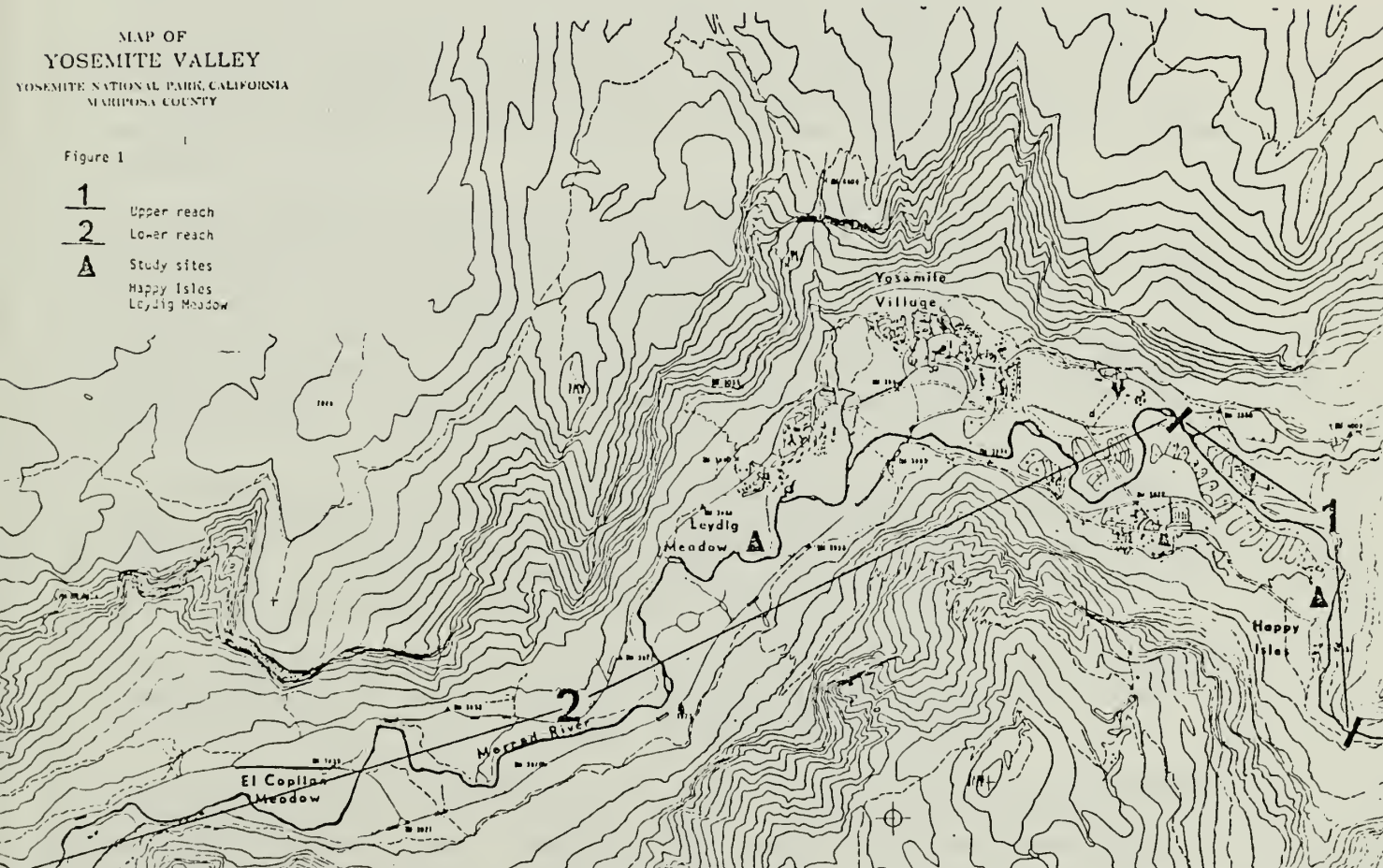
This report is submitted to the National Park Service (NPS) in fulfillment of a contract with the U.S. Fish and Wildlife Service (FWS) to conduct an instream flow study on the Merced River in Yosemite National Park (Park), using the FWS's Instream Flow Incremental Methodology. This report presents the final results of the flow study conducted between August 1982 to October 1983.

The NPS is planning the rehabilitation and enlargement of domestic and fire control water systems in Yosemite Valley. This instream flow study was conducted to assist the NPS to evaluate the aquatic resources in the Merced River and to determine the impacts of the proposed improvements on these resources, including fishing, swimming, rafting and other recreational activities.

This study was conducted as a cooperative effort with the NPS. Mr. Dick Riegelhuth, Chief Resource Officer, Yosemite National Park, and his staff, deserve recognition for the technical and field assistance provided in this study.

STUDY AREA

The Merced River originates in Yosemite National Park on the west slope of Mt. Lyell (12,912 feet) and descends 140 miles to where it joins the San Joaquin River in the Central Valley. The study area is within the uppermost reach of the Merced River. It begins 1,000 feet above the Happy Isles Bridge and extends 8 miles downstream to Pohono Bridge on the west end of the Yosemite Valley floor (Figure 1).



METHODS

Methodology

The Instream Flow Incremental Methodology (IFIM) developed by the FWS's Cooperative Instream Flow Group was used in this study. The hydraulic simulation program (IFG-4) and the habitat simulation program (HABTAT) were utilized to translate stream hydraulics into areas of usable fish habitat. The methodology is based on the assumptions that: (1) the physical variables of depth, velocity, temperature, and substrate are important quantifiable parameters affecting fish production which change with streamflow; (2) a direct relationship exists between availability and actual use of habitat by fish; (3) changes observed at a study site (a representative segment of a homogeneous reach) under study conditions are indicative of changes which would occur throughout that reach of the river; and (4) the hydraulic force of the selected flows will not alter the stream channel.

The study area was divided into two homogeneous habitat reaches and representative study sites were selected within these reaches by means of aerial photos, topographic maps and field reconnaissance (Figure 1). The first reach is characterized by a relatively steep gradient with fast-flowing waters, boulder and cobble substrate, and large native trees along the streambanks. The second reach is characterized by a relatively gradual gradient with medium- to slow-flowing waters, a gravel, sand and silt substrate, and grassy vegetation on the streambanks.

One representative study site (Figure 1) was selected within each habitat reach. The Happy Isles study site begins approximately 75 feet below the Happy Isles Bridge and extends downstream 633 feet (Figure 2). The Leydig Meadow study site begins approximately 800 feet below the swinging bridge near Leydig Meadow and extends 681 feet downstream (Figure 3).

These criteria were used for selection of study sites: (1) site representative of the habitat reach; (2) site accessible and workable; (3) site suitable for one or more life stages of the evaluation species.

A series of transect lines were established at each study site. Collection of hydrologic data such as velocity, depth and substrate was made at selected intervals on each transect line. These data points (verticals) were sampled at each flow. Schematic maps indicating location of the transect lines for the Happy Isles and Leydig Meadow reaches are included in Appendixes 1 and 2.

Permanent benchmarks were established at each study site to determine relative water surface elevations between transects at the measured flows and relative streambed profile elevations at each transect. The lowermost

Figure 2. Happy Isles Study Site, looking downstream from Happy Isles Bridge.

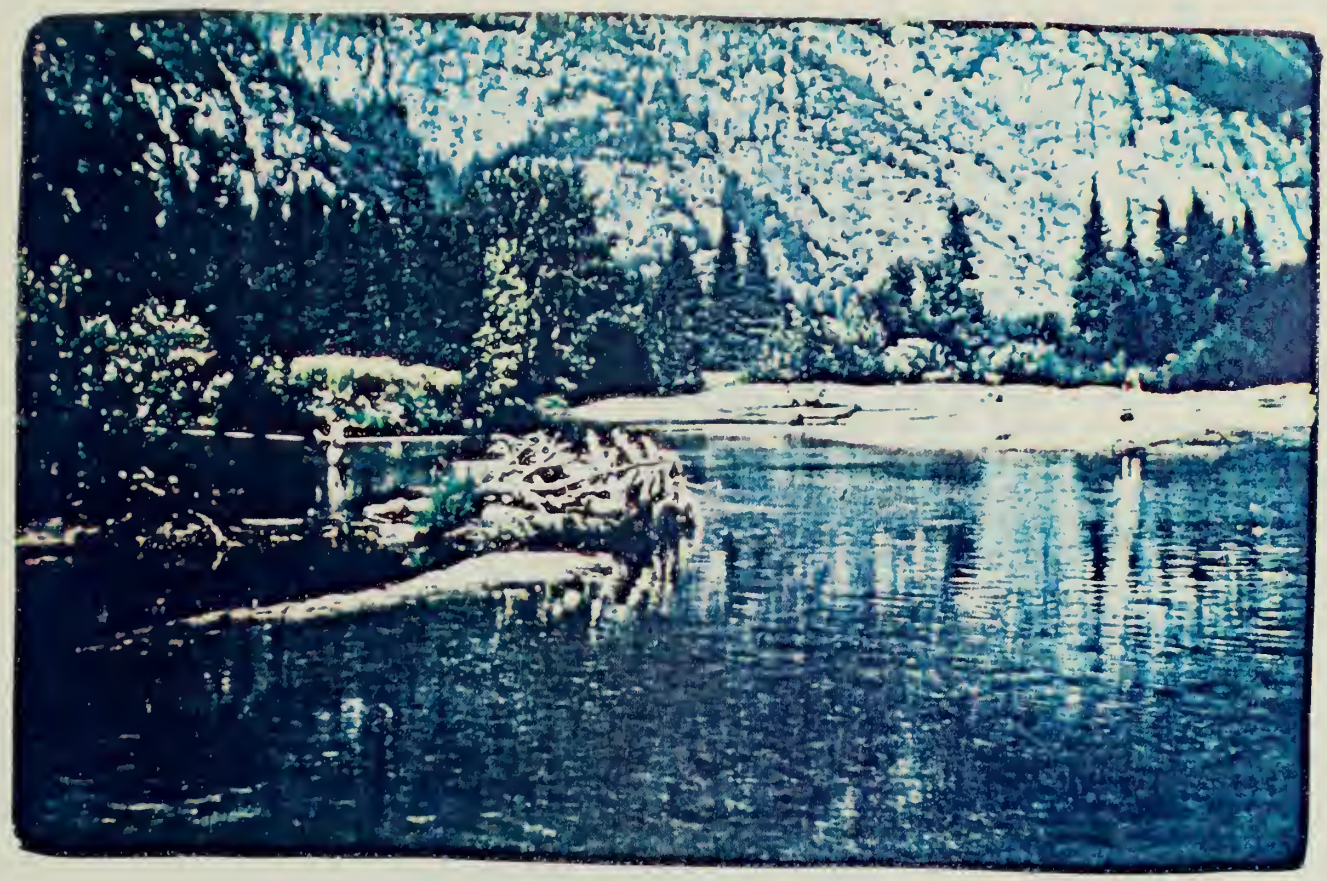


Figure 3 Looking upstream from lowest transect at Leydig Meadow study site

transect at each study site was placed at a hydraulic control to improve the hydraulic predictability of the IFG-4 model and to provide a good estimate of discharge at the study site. Headpins were placed on each riverbank at each transect above the estimated water level of the highest flow to be simulated with the model.

With a surveyor's level and 25-foot fiberglass stadia rod, and using basic surveying techniques, the elevation of each headpin was established in reference to the benchmark. Distances between transects were measured with a fiberglass tape. Streambed profile elevations were taken at one-foot intervals across each transect. Many of the interval measurements,or verticals, were deleted after the first flow measurement to reduce data collection effort to a level commensurate with funding and manpower.

Field data was collected between September 1982, and October 1983. The dates and locations of data collection are summarized in Table 1. Stream-flows were measured as runoff patterns allowed. Typically, the IFIM requires a minimum of three measured flows. Only two flows were measured in 1982 at the Happy Isles Reach because of high water which made data collection hazardous. The third flow was completed in the fall of 1983.

Table 1. Study periods and Measured Flows for the Merced River Flow Study, 1982-1983.

Location (study reach)	Date	Flow in cfs	Comments
Happy Isles	November 16, 1982	147	High Flow
	October 14, 1983	84	Middle Flow
	September 21, 1982	41	Low Flow
Leydig Meadow	November 4, 1982	403	High Flow
	October 17, 1982	256	Middle Flow
	September 22, 1982	48	Low Flow

Velocities were measured as mean column velocity at each vertical using Marsh-McBirney electronic flow meters (Model 201). One velocity measurement was taken at each vertical at 0.6 of the total depth (from the surface) for depths of less than 2.5 feet. Two measurements were taken at 0.2 and 0.8 of the total depth and averaged for depths 2.5 feet and greater. Depths were measured with top-setting wading rods to the nearest 0.1 foot (Figure 4).

In waters too deep and too fast for the top-setting wading rods, flow meter probes were attached to a 50-pound weight (bomb) and suspended from a steel cable and pulley system from a boat. Steel cables were strung across the river to hold the boat while depth and velocity measurements were taken (Figure 5).

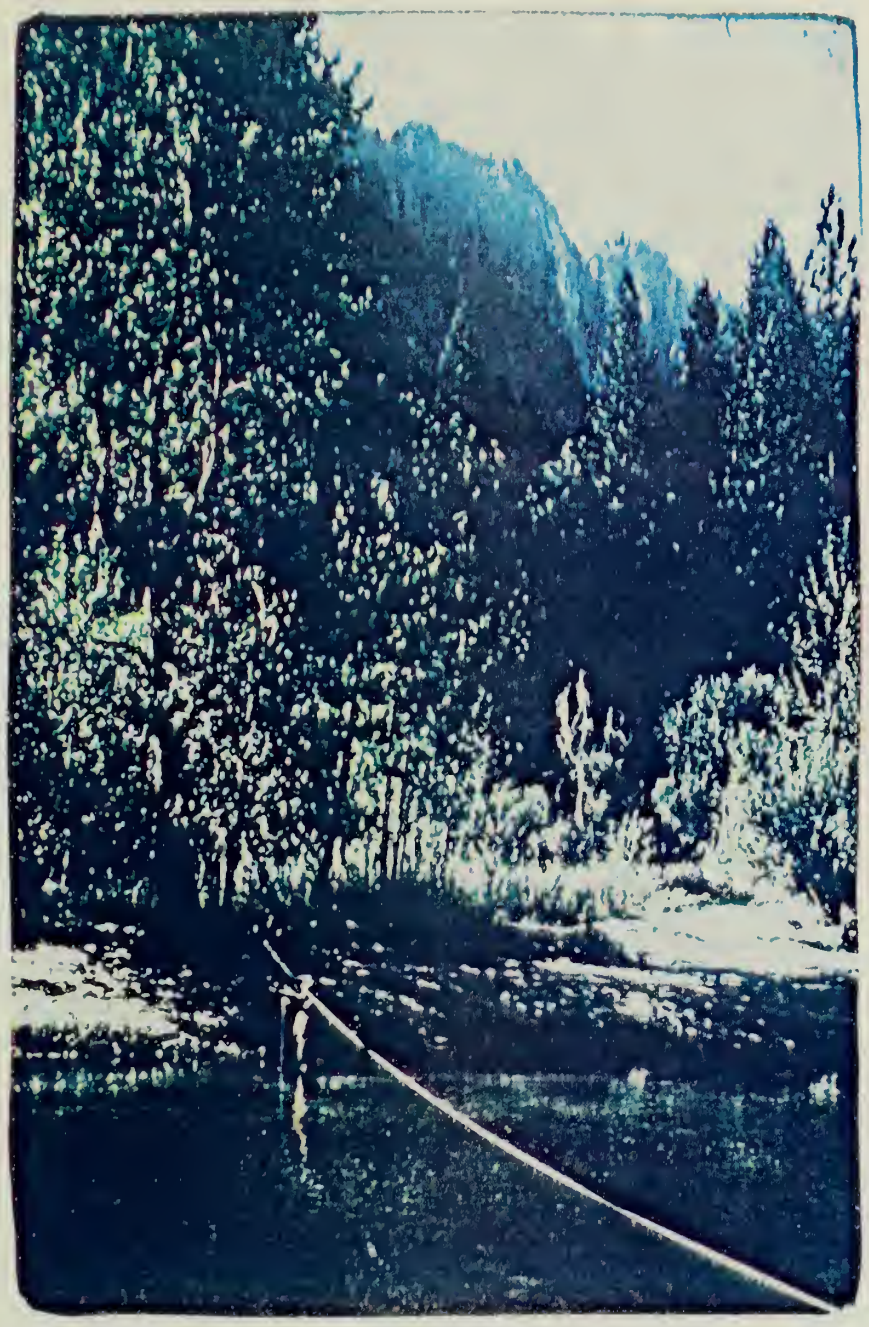


Figure 4. Measuring depths and velocities with a top-setting wading rod.

Figure 5. Measuring depths and velocities with the boat apparatus.

Water surface elevations at each transect were taken at each measured flow and referenced to the benchmark. During low flow data collection, substrate conditions were rated at each vertical according to the Modified Wentworth Substrate Index (Appendix 3).

Habitat preference curves used in calculating potential habitat were those developed by Bovee (1978) and Hyra (1978). Preference curves used in this study were those for the life stages of rainbow trout (Appendix 4). In addition, the NPS requested that specific recreational use curves be used in the habitat evaluation. The curves used are presented in Appendix 5. Additional recreational preference curves available are listed in Appendix 6.

Data input for computer processing was initiated in December 1982 using procedures provided by Bovee (1982). Data processing was accomplished using the Bureau of Reclamation's Cyber computer in Denver, Colorado, and the National Oceanic and Atmospheric Administration's Cyber computer in Boulder, Colorado.

The Instream Flow Group's IFG-4 hydraulic simulation program was used to establish a stage-discharge relationship for each study site. Using this relationship, along with species preference curves, the HABTAT program was then used to calculate available habitat (per 1,000 feet of stream) for each species and life stage for flows ranging from 1 to 600 cubic feet per second (cfs). The program was also used to calculate recreational area vs. flow.

Evaluation Species

Selection of evaluation species is an important element of the IFIM analysis. One or more species are chosen to serve as indicator species based on such factors as their sensitivity to specific environmental conditions, importance as a game fish, or threatened or endangered status. In this study we selected the rainbow trout, a principal sport fish in the river for evaluation.

To insure that the appropriate evaluation species was selected, the fish population was sampled by electroshocking a representative site approximately 100 feet in length within each study reach. Seines were used to block off each end of the sampling site to insure a captive population. A crew of five, equipped with hand nets, buckets and backpack electroshocker, made three passes of the sampling area. Captured fish were placed in containers according to pass number. Trout captured were identified by species, weighed, measured and observed for general condition. Data collected is presented in Appendix 6. Estimates of population size or productivity were not made because of insufficient data.

During the first electroshocking effort in the upper reach below Happy Isles Bridge, we encountered low amperage problems. We were able to increase amperage from approximately 0.2 to 0.4 by addition of salt to the stream. The salt was introduced approximately 50 yards upstream of

Table 2. Water Quality Requirements for Rainbow Trout

	Water Temp. (°F)	Dissolved Oxygen (mg/l)	pH	Alkalinity (mg/l)	Carbon Dioxide (mg/l)	Turbidity (JTU)
Adult	32-70	5.0-SAT.	6.0-8.0	10-400	0-10	10
Spawning	42-55	Near SAT.	6.0-8.0	10-400	0-10	10
Rearing	50-60	7.0-SAT.	6.0-8.0	10-400	0-10	10

Table 3. Life Stage Periodicity Chart

for

Rainbow Trout in Merced River

	Jan.	Feb.	March	Apr.	May	Jun.	July	Aug.	Sept.	Oct.	Nov.	Dec.
Adult Holding	X	X	X	X	X	X	X	X	X	X	X	X
Spawning			X	X	X	X						
Egg Incubation			X	X	X	X	X					
Fry						X	X	X				
Rearing	X	X	X	X	X	X	X	X	X	X	X	X

the sample area and allowed to mix and move downstream before electroshocking passes were made. Although the electroshocker output was reduced from a normal 0.8 apmeres to 0.4 amperes, it is believed that fish of all species likely to be present in the stream were collected.

Environmental Requirements

In order to fully assess potential impacts of water withdrawals on fish species it is important to consider food, cover and water quality requirements.

Although the study effort did not include a detailed assessment of fish food availability, observations were made on the condition factor of fish captured and notations made for each species based on the ratio of body length to body width. Because the observations were made in the late summer and early fall, it is believed that poor food availability would have been revealed by poor condition.

The IFIM affords options to assess both substrate and cover conditions. The modified Wentworth Substrate Index for substrate assessment was used. This index consists of a series of codes denoting size classes of substrate particles (Appendix 2). In the IFIM method, a substrate code is given to each vertical data point on a transect. The substrate rating is then incorporated into the habitat model based on preferences which fish exhibit for the substrate. Because substrate can function as instream cover for fishes, the substrate assessment is also partially an assessment of instream cover. For example, if a transect contained primarily vertical data points rated at 6.0 (cobble) this can be interpreted as a location likely to provide good instream cover for juvenile trout.

Because the IFIM cover index is relatively new and untried, it was not used in the study. We did, however, note general streamside cover within each of the study areas.

Based upon a literature review and professional judgment, key water quality requirements were designated for the evaluation species (Table 2). Although the ranges presented in the tables are broad, they are generally applicable to high quality fishery habitat.

Also, a life cycle periodicity chart for the evaluation species was prepared to show the time periods when the species is at each stage of its life cycle (Table 3). The water quality requirements of each species vary with life cycle stages, e.g., higher levels of water flow and oxygen are generally required during the spawning and incubation stages than at other stages.

The nature of the study effort and limited time frame precluded detailed water quality sampling by our personnel; however, the U.S. Geological Survey (USGS) is currently collecting information for a special study at several locations on the Merced River. In addition, the USGS maintains permanent water sampling stations near our Happy Isles study site and at Pohono Bridge below our Leydig Meadow study site. The USGS station at Happy Isles regularly records a large number of water quality parameters, including temperature, streamflow, dissolved gases, metallic ions, organic and inorganic compounds, bacterial decomposition, and pesticides. At Pohono Bridge stage and discharge are recorded.

Water quality requirements (Table 2), the life cycle periodicity chart (Table 3), and other water quality information derived from USGS records were used to define current fishery habitat conditions in the study area and possible future conditions with various schemes of water withdrawals. A USGS report that describes an assessment of water quality conditions during the 1977 drought year (Sorenson and Hoffman, 1981) was helpful.

Tributary influence below the Happy Isles study site also needed to be considered. Tributaries such as Tenaya Creek, Royal Arch Creek, Indian Canyon Creek, Yosemite Creek, Sentinel Creek, Bridalveil Creek and Ribbon Creek likely affect water quality in the study reach. Water quality data is not available for these tributary streams other than streamflow for Tenaya Creek.

Because of very limited water quality data for the Leydig Meadow reach, our comments on water quality apply primarily to the Happy Isles reach.

RESULTS

Streamflow

Using the standard velocity adjustment factor range of 0.9 to 1.1, the measured flows of 41 cfs, 84 cfs and 147 cfs at the Happy Isles study site permitted a simulation of flows ranging from 48 to 200 cfs. Confidence in the validity of the flow - habitat relationship within this range is good. Because it is also important in our analysis to look at flows lower than 48 cfs, and greater than 200 cfs, we extrapolated outside this range, recognizing the limitations in our data. We felt this was necessary and justified as we had no better information to use. Therefore, you will note that in some cases the flow vs. available habitat Tables (Appendix 8) and Figures 6 and 7 extend from 1 cfs to beyond the upper limit set by the 1.1 velocity adjustment range. Similarly, using the velocity adjustment range of 0.9 to 1.1, the measured flows of 48, 256 and 403 cfs at the Leydig Meadow site permitted a simulation of flows from 48 to 403 cfs. Once again because of the need to assess habitat at a greater range of flows, we extrapolated to 1 cfs and 600 cfs.

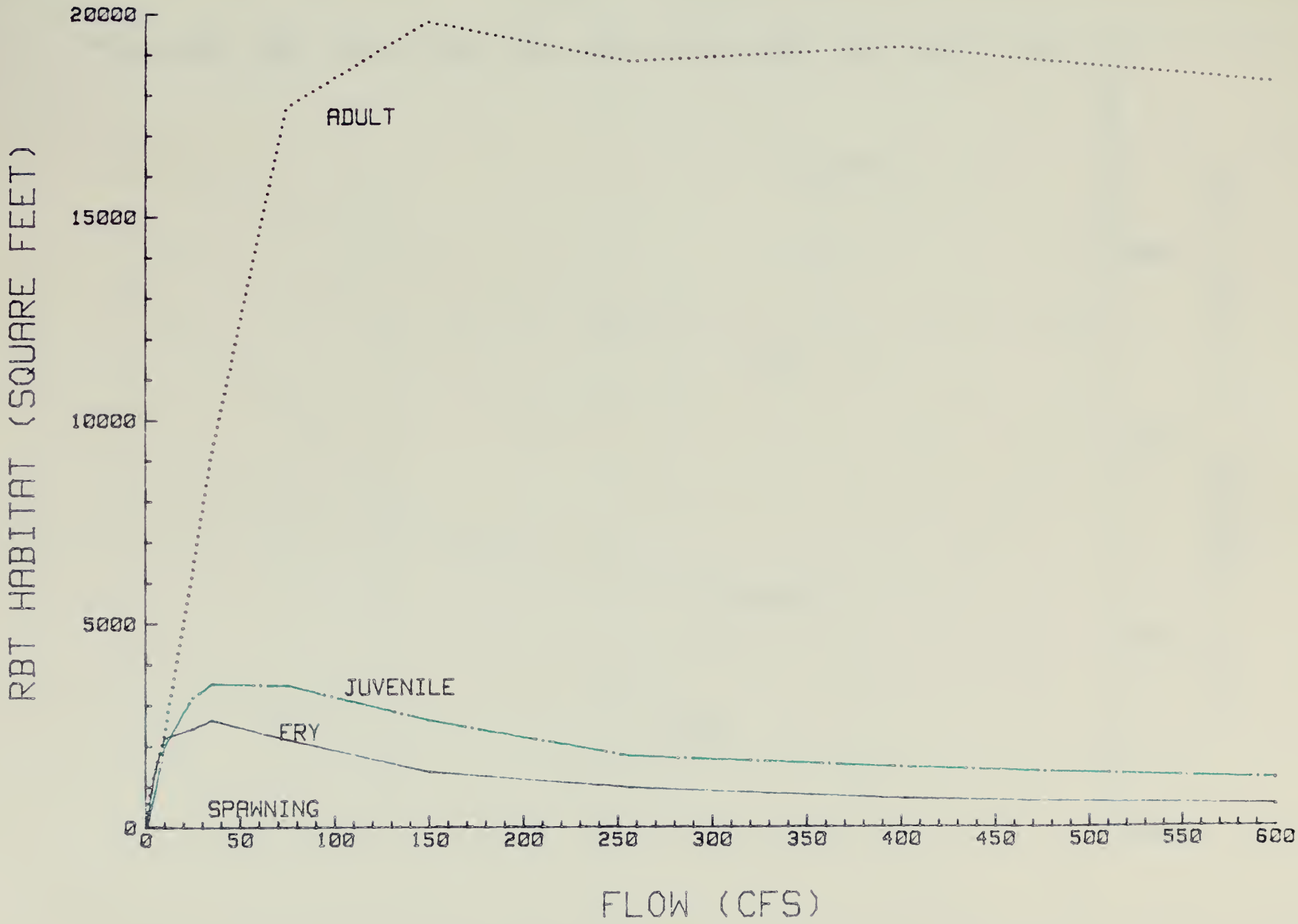
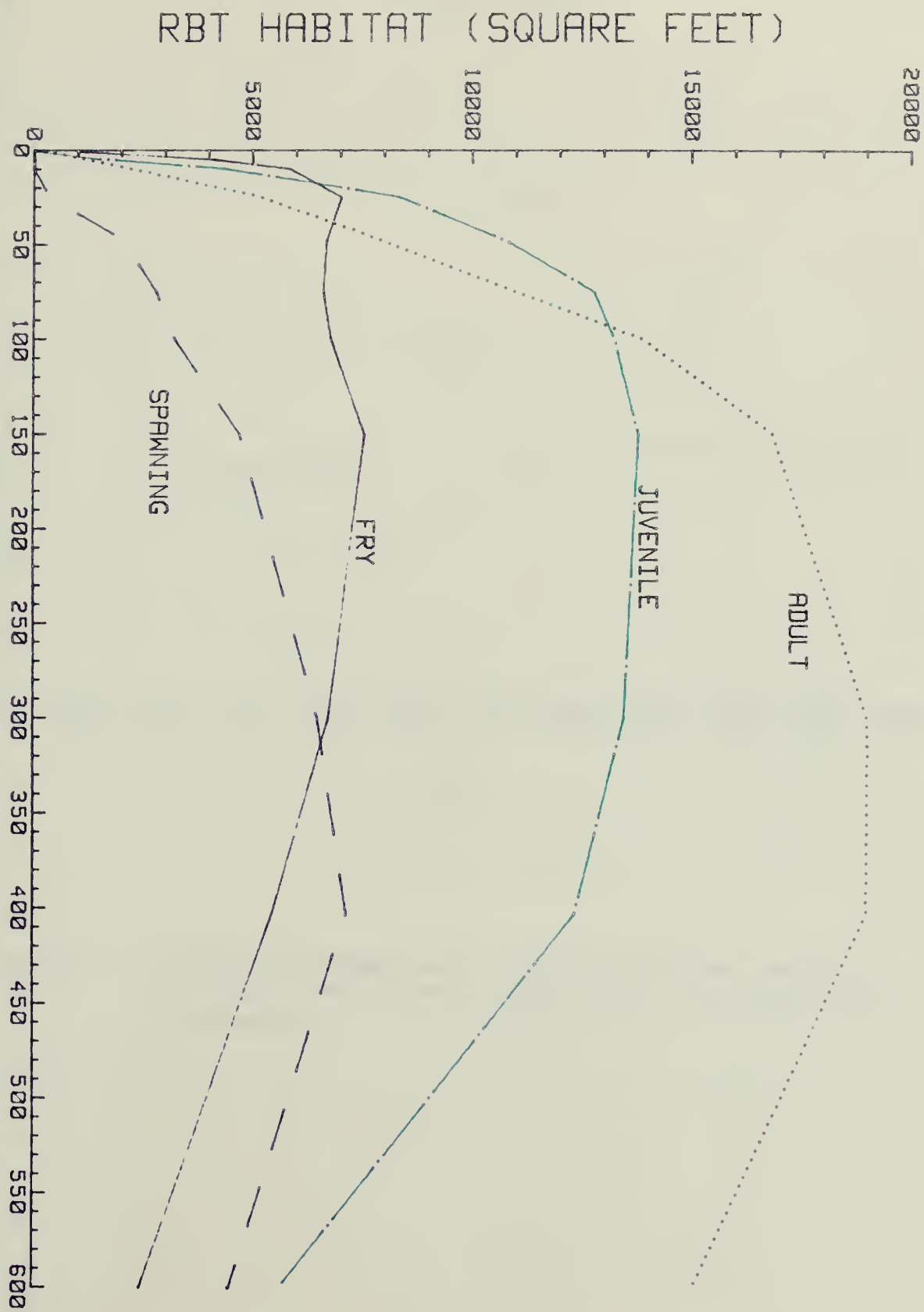


Fig. 6. Flow versus available habitat per 1,000 feet of stream for rainbow trout in Happy Isles reach.


RBT HABITAT (SQUARE FEET)
0
5000
10000
15000
20000
FLOW (CFS)
0
50
100
150
200
250
300
350
400
450
500
550
600
SPAWNING
FRY
JUVENILE
ADULT

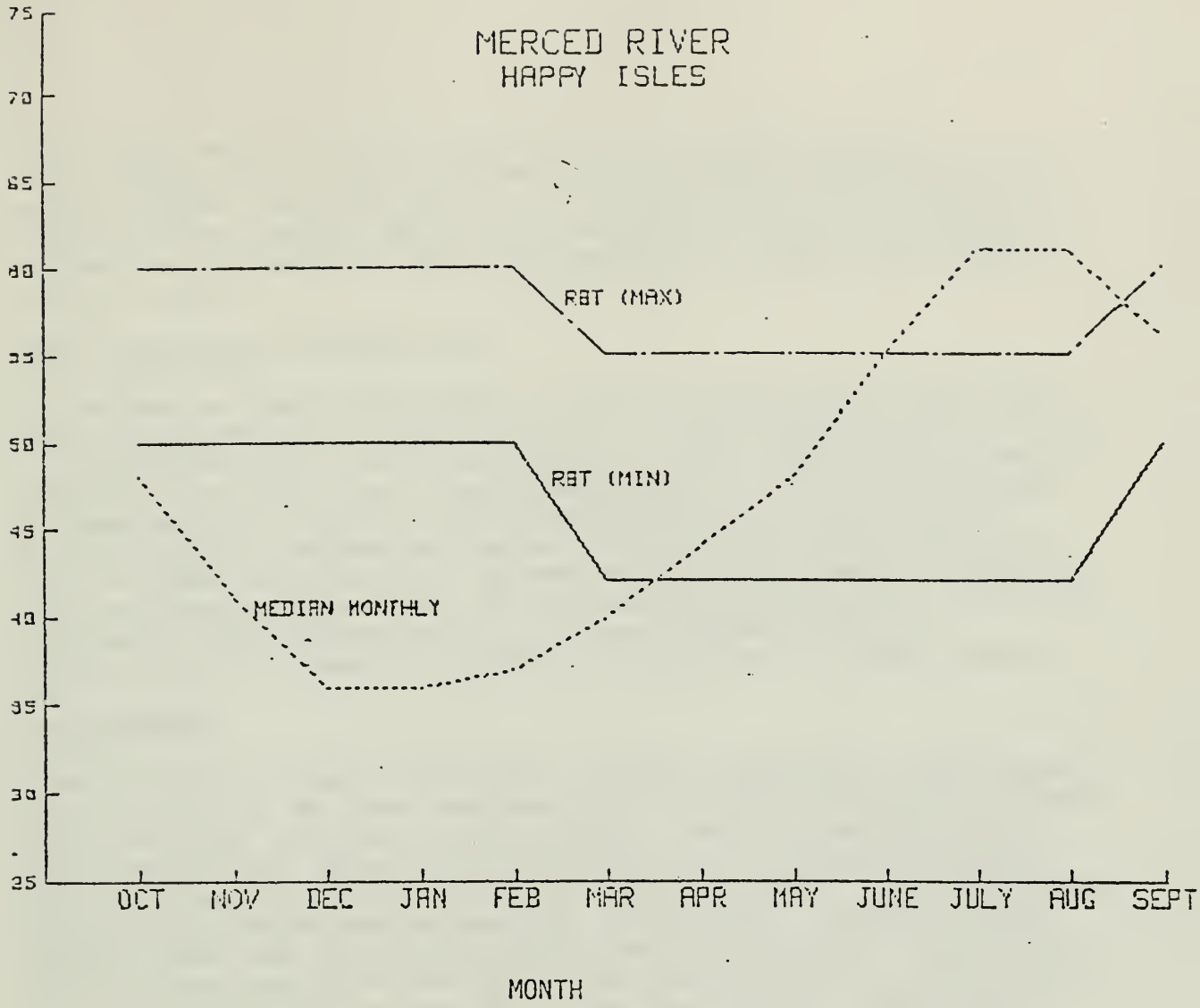


Figure 8. Comparison between monthly water temperature recorded at Happy Isles for period (1966-1982) and rainbow trout requirements.

Flow range from 1 cfs to 600 cfs was used in the HABTAT program to estimate habitat area for rainbow trout in the Happy Isles and Leydig Meadow reaches. The areas (sq. ft.) of available habitat per 1,000 feet of stream at flows from 1 to 600 cfs for the Happy Isles and Leydig Meadow reaches for fry, juvenile, adult and spawning life stages are presented in Figures 6 and 7.

Happy Isles Reach (Rainbow Trout)

The maximum available habitat (mah) for adult rainbow trout occurs with a flow of approximately 150 cfs (Figure 6). At flows less than 100 cfs there is a significant reduction of adult habitat. The maximum habitat area for spawning occurs with flows of approximately 200 cfs. The relative amount of spawning habitat was very low primarily due to oversized substrate. Rainbow trout fry have maximum habitat area at flows of approximately 25 cfs. At flows less than 20 cfs or greater than 48 cfs there is a significant reduction in fry habitat. Rainbow juveniles have maximum habitat area at flows of approximately 48 cfs. At flows less than 30 cfs or greater than 75 cfs there is a significant reduction in juvenile habitat.

Leydig Meadow

FLows of 256 cfs produce near-maximum available habitat for adult rainbow trout (Figure 7). At flows less than 200 cfs or greater than 403 cfs there is a significant reduction in adult habitat. Mah for spawning occurs at flows near 403 cfs. Reducing flow to 256 cfs or increasing flow above 403 cfs causes significant reduction in spawning habitat. Relative amounts of available spawning habitat were high in this reach. Several optimal spawning areas were observed during our field study effort. Flows of 150 cfs produce mah for rainbow fry. Significant reduction in fry habitat occurs with flows greater than 256 or less than 100 cfs. Near-maximum available habitat for juveniles occurs at a flow of 200 cfs. Flows less than 100 cfs or greater than 256 cfs mean a significant reduction in juvenile habitat.

Streamflow vs. Recreational Area

The findings concerning recreational area vs. flow are presented in tabular form in Appendixes 9 and 10. At the request of the NPS, we did not perform an analysis of the recreational data. The NPS preferred that effort not be expended on such analysis until time and manpower are available to test the applicability of the recreational preference curves.

Water Quality

Temperature

Generally, water temperatures during all months of the year in the Happy Isles reach are suitable for rainbow (Figure 8), but there are times when

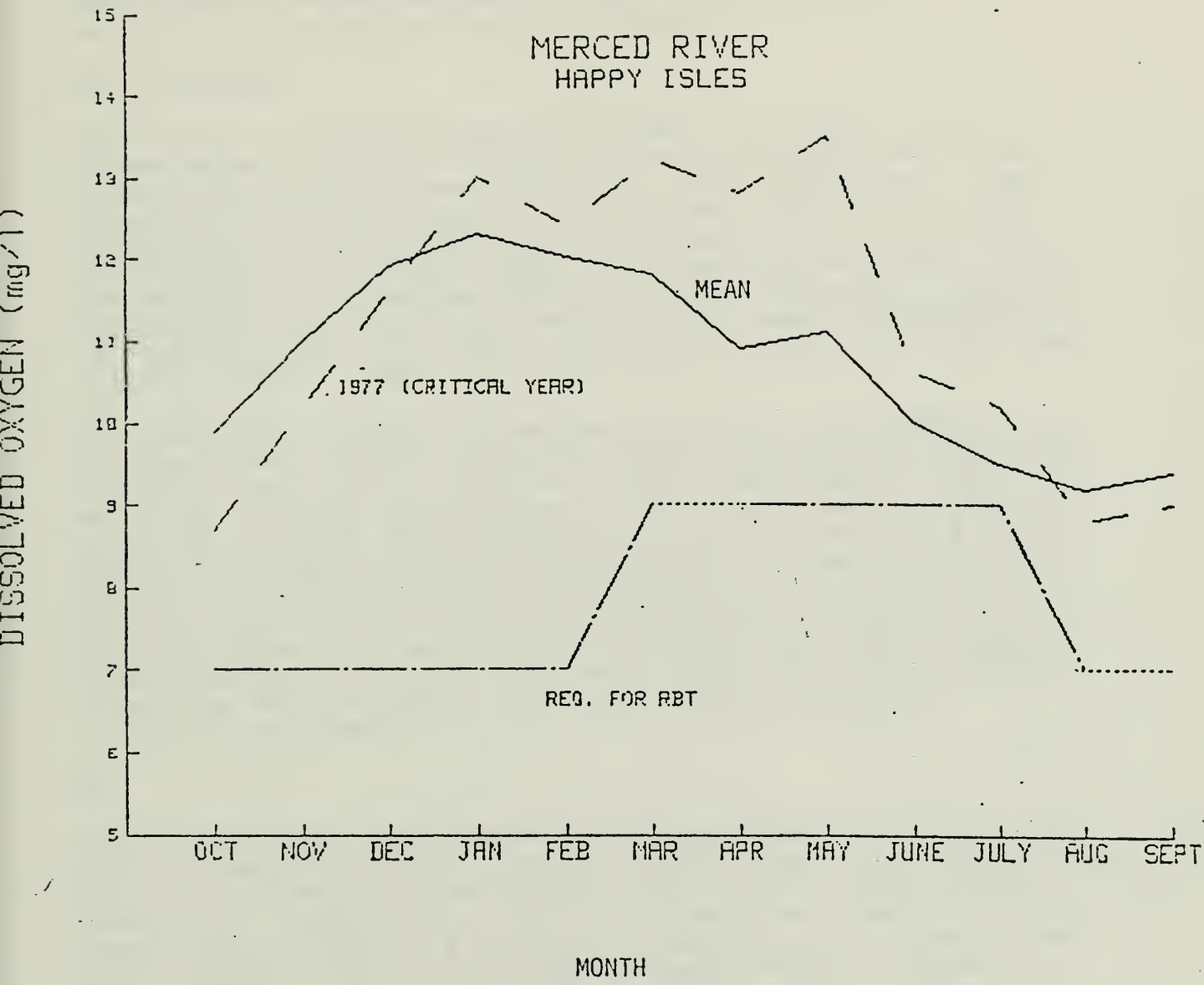


Figure 9. Comparison between mean monthly dissolved oxygen levels recorded at Happy Isles (1975-1982) and rainbow trout requirements.

temperatures are either above or below the optimum for the relevant stage in the trout life cycle. These deviations from ideal water temperature probably reduce overall fish production. As indicated in Figure 8, spawning temperatures for rainbow trout are very good. Rearing water temperatures for rainbow are generally good, with ideal growth temperatures occurring from June through October.

Dissolved Oxygen

Dissolved (d.o.) levels near Happy Isles appear to be nearly ideal for rainbow during all months of the year. According to USGS records from October 1975 to July 1982, mean monthly d.o. levels ranged from 9.2. mg/1 in August to 12.3 mg/1 in January. The mean monthly d.o. levels, along with required levels for rainbow trout are shown in Figure 9. USGS data collected during the 1977 water year, one of the driest on record, provide some insight into how low flow affects d.o. levels (Figure 9). The record indicates that during the month of August in 1977, when streamflows were at a minimum of 4.5 cfs, d.o. levels fell to about 8.5 mg/1, still within the acceptable range for trout.

During August and September, streamflows in the Merced River generally reach their lowest levels and many tributaries dry up. At this time, water temperatures rise and d.o. levels fall to their lowest levels. USGS water records for the Pohono Bridge Station, near the Leydig Meadow reach, in August 1981 and August 1982 indicate d.o. levels of 8.2 mg/1 and 8.7 mg/1, respectively. Samples taken at Happy Isles station on August 6, 1981 and August 24, 1981 gave d.o. readings of 8.3 mg/1 and 8.6 mg/1, respectively. While these data are minimal, there is an indication that water quality in the Leydig Meadow reach, with respect to dissolved oxygen, may not differ greatly from that of the Happy Isles reach. More water quality studies on a continuous basis are needed in the lower reach before any firm conclusions can be made.

pH

pH levels near Happy Isles are within the range suitable for rainbow trout during all months of the year. Based on USGS data from October 1975 to July 1982, the mean monthly pH levels ranged from 6.5 to 6.8, with an average value of 6.7. Although there is very little variation in mean monthly pH, there is some variation on a daily basis. Generally, the extremes are well within acceptable limits for the aquatic resource overall. Recorded mean monthly pH, and pH requirements for rainbow, are shown in Figure 10.

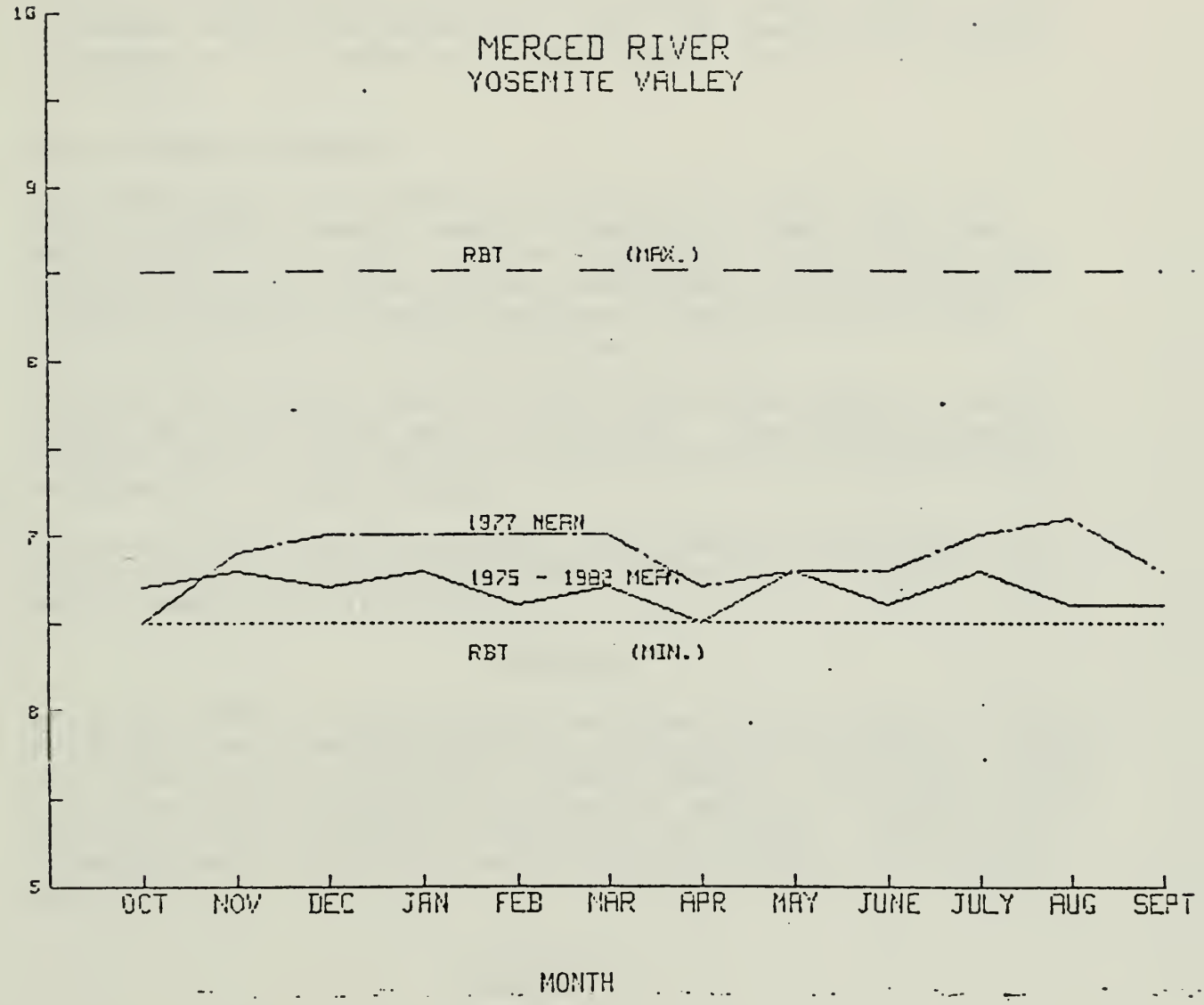


Figure 10. Mean monthly pH (1975-1982), and critical year pH (1977) compared with required pH for rainbow trout.

USGS records show that pH testing was done at the Pohono Bridge station, near Leydig Meadow reach, on August 19, 1981 and August 17, 1982. The readings were 5.9 and 7.0, respectively. While this data is minimal, it indicates that pH during some periods may be below the recommended level. Readings taken at Happy Isles on August 6, 1981, August 24, 1981 and July 23, 1982 were 6.0, 6.1, and 6.0, respectively. Apparently, some difference occurs in pH between the reaches, but based on this data the difference would not appear to be significant in terms of fish habitat suitability.

Other Chemical Parameters

USGS measurements of CO_2 levels in the Happy Isles reach from October 1975 to July 1982 showed a range of 0.3 mg/1 to 5.2 mg/1, with a mean monthly level of 1.7 mg/1. Alkalinity measurements for the same period ranged from 1 mg/1 to 10 mg/1, with a mean monthly level of 5.8 mg/11. Turbidity levels for the period, measured in Jackson Turbidity Units (JTU), ranged from 0 to 1, with an average of 0.75.

These CO_2 and turbidity levels are within the expected range for natural streams that provide high quality fish habitat. The alkalinity levels, although very low, are typical of streams originating in a granite-based watershed low in soluble minerals.

A cursory review of other parameters, such as metallic ions known to be toxic to fish, did not reveal any likely problem areas. Generally, water quality appears to be satisfactory.

DISCUSSION

To assist the NPS in regulating water withdrawals from the Merced River, we developed a flow schedule (Table 4) for each of the study reaches. Because river flows are uncontrolled and fluctuate seasonally, and because species life stage needs vary seasonably, it would be impossible to formulate and implement a truly optimum flow schedule for the fishery. Therefore, the following schedule should be viewed as a general guideline for planning purposes.

Table 4

Instream Flow Needs For Rainbow Trout

Merced River
Yosemite, California

Instream Flow Downstream of Proposed Point of Diversion (cubic feet per second) •

	Happy Isle	Life Stage	Leydig Meadow	Life Stage
Oct.	48	Juvenile	200	Juvenile
Nov.	48		200	
Dec.	48		200	
Jan.	48		200	
Feb.	48		200	
Mar.	150	Adult Holding	403	Spawning
Apr.	150		403	
May	150		403	
June	150		403	
July	150		403	
Aug.	48	Juvenile	150	Fry
Sept.	48		200	Juvenile

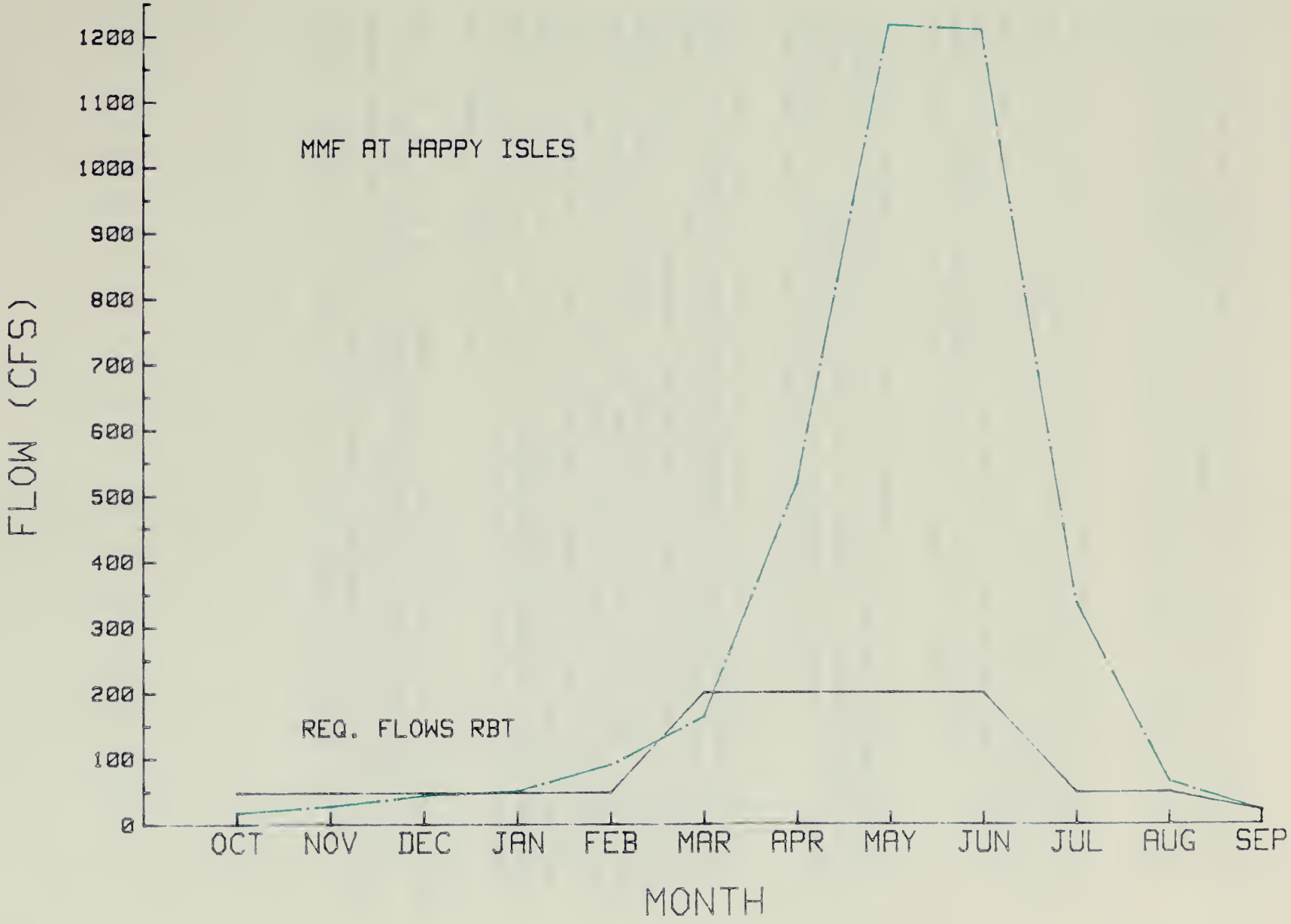


Fig. 11. Median monthly flows at Happy Isles (1916-1982) and required flows to achieve maximum available habitat for rainbow trout.

These flows were developed from the life cycle information in Table 3 and the flow versus habitat values in Appendix 8. In most cases the flow listed for a particular month represents the flow that provides maximum habitat area for the life stage that we consider most important for the month.

For example, we felt that adult holding during March through July and juvenile rearing from August through February represent the most important uses of habitat in the Happy Isles reach. From the data in Appendix 8, we determined that a flow of 48 cfs is needed to provide maximum juvenile habitat and a flow of 150 cfs is needed to provide maximum adult holding habitat. Although some spawning habitat is present, the amount is inadequate to justify a different flow for spawning purposes.

In Table 4, we have given a flow requirement for the July portion of the incubation life stage at the end of the spawning period for the Leydig Meadow reach. We used the same flow as needed for spawning under the assumption that developing eggs would be adequately protected if spawning flow levels were retained through the incubation period.

The flows listed in Table 4 are considerably above those which occur naturally for much of the year and somewhat below natural flows at other times. These flows are for information purposes only and should not be considered as a recommended flow regime for the Merced River. According to the NPS, there are no plans to regulate or control flows in the river other than the incidental control that occurs during the 3 cfs water withdrawals in low flow periods. At other times during the year, the 3 cfs withdrawals would have minimal influence on the total amount of flow. It would be possible to develop a single flow regime which would provide the maximum habitat for various life stages in both reaches combined. But since flows will remain uncontrolled on the mainstem and tributaries, such a regime would serve no useful purpose.

The flows in Table 4 are ideal, i.e., the flows that would provide optimum or near optimum habitat in each stream reach. They do not occur in all months under naturally conditions. Ideal flows for rainbow trout and natural occurring median monthly flows in the Happy Isles and Leydig Meadow reaches are shown in Figures 11 and 12 and listed in Appendix 11.

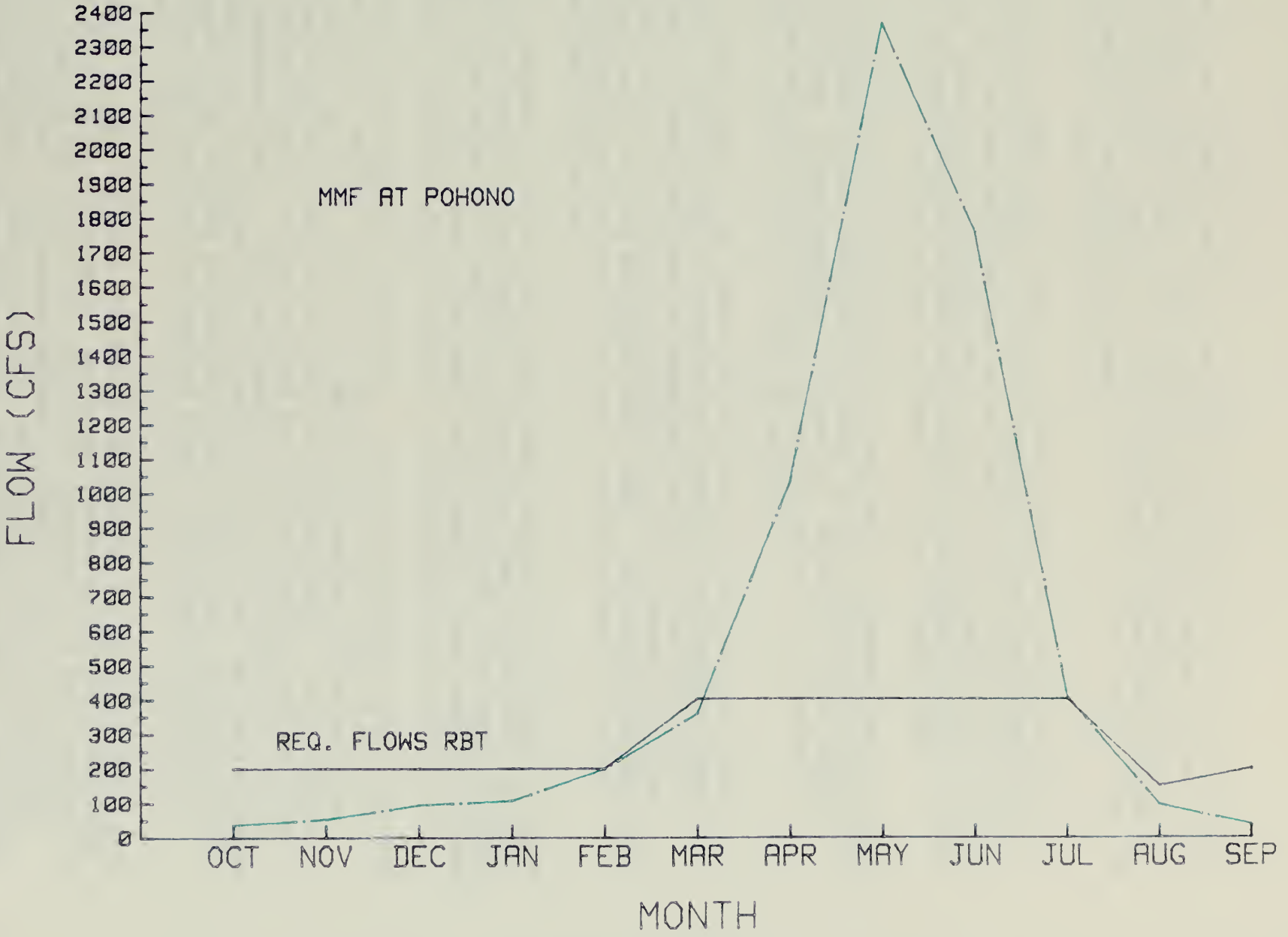


Fig. 12. Median monthly flows at Pohono Bridge (1917-1982) and required flows to achieve maximum available habitat for rainbow trout.

Comparison of median monthly flows (M.M.F.) at Happy Isles (for the period 1916-1982) to the flows required there provides some perspective on potential impact issues. The M.M.F. occurring in the Happy Isles reach met or exceeded flows required for maximum available rainbow trout habitat in the months of January through August. M.M.F. were below required levels in September through December (Figure 11).

Similarly, comparison of M.M.F. at Pohono Bridge (for the period 1917-1982) recorded at Pohono to the flows required in the Leydig Meadow reach provides an interesting perspective on impact issues (Figure 12). The M.M.F. occurring in the Leydig Meadow reach met or exceeded required flows for maximum available rainbow trout habitat in the months of April through July. M.M.F. were below required levels in August through March.

In summary, M.M.F. in the Happy Isles reach met or exceeded required levels for optimum rainbow trout habitat in most months except the low flow period of September through December. In contrast, the M.M.F. in the Leydig Meadow reach were less than required in most months except during the typical high flow period of April through July.

The Merced River is the current water source for human use in Yosemite Valley. Surface water is diverted and treated at a plant above Happy Isles. A recent environmental assessment on the planned water system rehabilitation stated that approximately 2.9 cfs is needed daily for potable water and fire protection (NPS, 1983). Two sources, surface water and ground water, are being considered, with ground water being the preferred alternative.

FWS attempted to measure the lowest summer flow possible in order to assess low flow impacts on the fishery. But because flows in the 1982 water year were above normal, the lowest flows measured were 41 cfs at Happy Isles and 48 cfs at Leydig Meadow. The lowest median monthly flows recorded at Happy Isles range from 17-20 cfs; those at Leydig Meadow range from 36-52 cfs.

Results of the hydraulic simulation, using the recommended velocity adjustment factor range of 0.9 to 1.1, limits the reliable range of habitat projection to flows of 48 cfs to 200 cfs for the Happy Isles Reach and flows of 48 cfs to 403 cfs for the Leydig Meadow Reach. For discussion purposes, however, we have included the habitat simulated outside these recommended limits. Since the greatest habitat reductions occur at the lower flows, we thought it was important to retain the low flow simulation because it is the best estimate available at this time. We would need to collect additional data at measured flows in the range of 10-30 cfs to insure that we met the velocity adjustment guidelines at lower flows.

Keeping in mind the data limitations, we examined the habitat changes that occur with 3 cfs withdrawals. We focused our analysis on the life stages and required habitats in each reach which appeared to be most important to fish production. We examined changes in juvenile habitat in the Happy Isles Reach and changes in juvenile and spawning habitat in the Leydig Meadow Reach. We reduced the normal median monthly flows by 3 cfs during the months when those life stages occur and calculated percentage habitat losses (Tables 5 and 6).

Table 5. Habitat Changes Caused by 3 cfs Withdrawals at Happy Isles.

Period	Normal Flow (cfs)	Less 3 cfs	Juvenile Habitat Normal Habitat Area/1000 feet	Less 3 cfs	% Change
Oct.	17	14	2897	2544	-12.2
Nov.	27	24	3287	3146	- 4.3
Mar.	163	160	2470	2505	+ 1.4
July	339	336	1569	1577	+ .5
Aug.	64	61	3569	3573	+ .3
Sept.	20	17	3110	2997	- 6.8

Table 6. Habitat Changes Caused by 3 cfs Withdrawals at Leydig Meadow.

Period	Juvenile Habitat Normal Flow	Less 3 cfs	Normal Habitat Area/1000 feet	Less 3 cfs	% Change	Spawning Habitat Normal Habitat Area/1000 feet	Less 3 cfs	% Change
Oct.	36	33	9,336	8,899	-5.0	1,291	1,033	-20.0
Nov.	52	49	10,996	10,790	-1.9	2,018	1,891	- 6.3
Mar.	359	356	13,532	13,440	- .7	6,675	6,659	- 0.2
July	407	404	12,155	12,278	+1.0	7,174	7,142	- 0.4
Aug.	93	91	13,134	13,131	-0.2	3,107	3,059	- 1.5
Sept.	36	33	9,336	8,899	-5.0	1,291	1,033	-20.0

CONCLUSIONS

Happy Isles

Juvenile Stage

When flows in the Happy Isles Reach are near 20 cfs or lower, flow reductions of 3 cfs or more would cause significant loss of juvenile habitat. Because flows in normal water years typically are less than 20 cfs in September, October and November, an alternative water supply would be needed in those months to insure that juvenile habitat is protected. In below normal water years the alternative water supply may be needed in other low flow months also.

Leydig Meadow

Juvenile Stage

When flows in the Leydig Meadow Reach are near 36 cfs or less, flow reductions of 3 cfs or greater would cause significant loss of juvenile habitat. Because flows this low typically occur in September and October, an alternate water supply would be needed in these months to prevent juvenile habitat loss.

Spawning Stage

When flows in the Leydig Meadow Reach are near 52 cfs or less, flow reductions of 3 cfs or greater would cause significant loss of spawning habitat. Generally flows during the spawning period in March-June range from 300 to 1700 cfs so there should not be any problem with 3 cfs withdrawals insofar as spawning is concerned.

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Appendix

1

Field Drawing

of

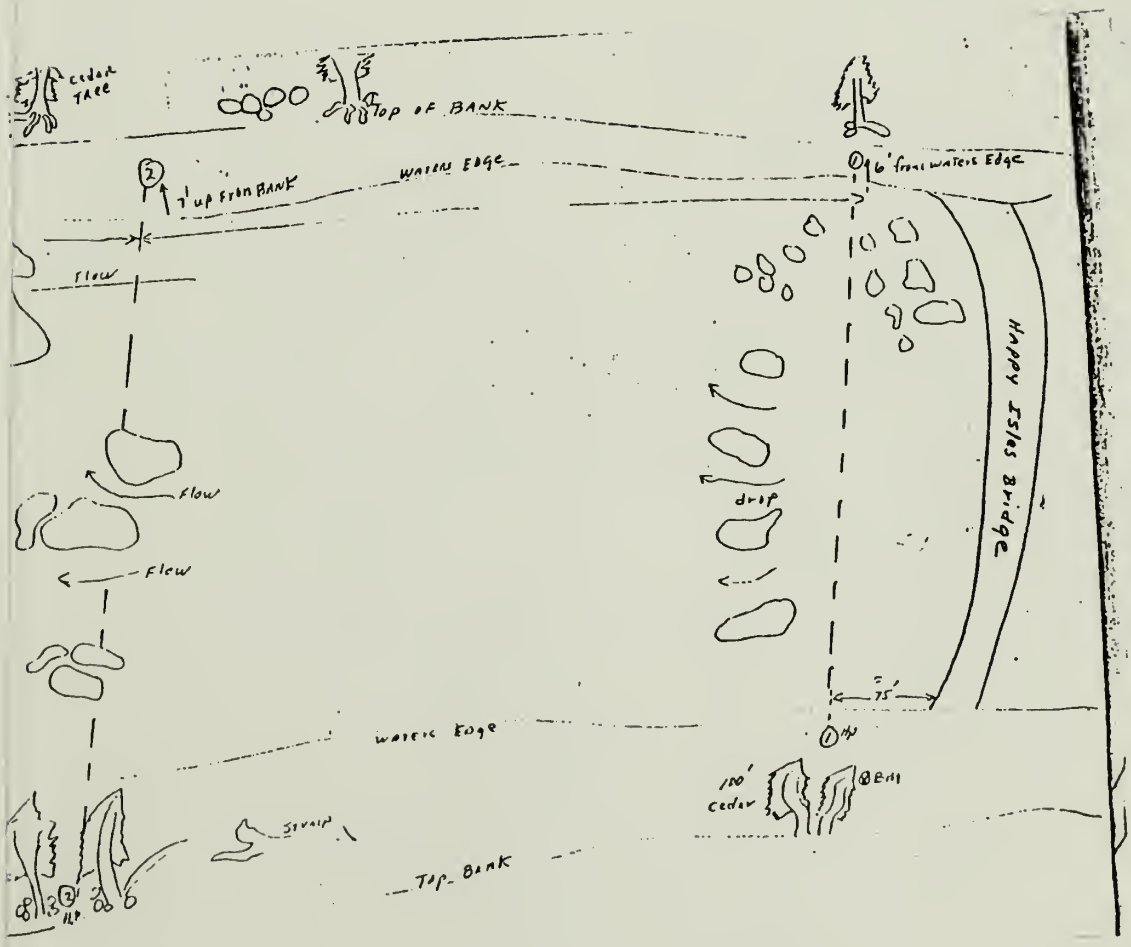
Happy Isles

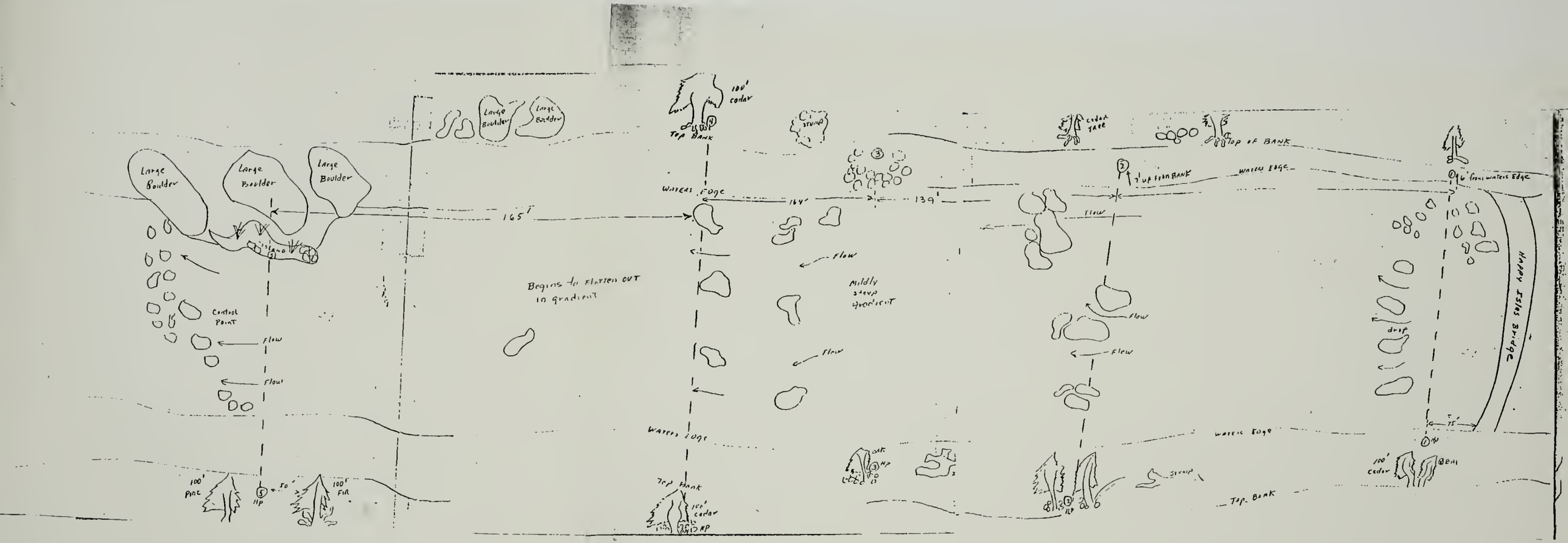
Study

Site

Appendix

2


cedar tree
top of bank
water edge
1' up from bank
flow
flow
flow
drop
96' from waters edge
Navy Isis Bridge
75'
water edge
100' cedar
BM
Top Bank


Large Boulder
Large Boulder
Large Boulder
Large Boulder
Large Boulder
165'
Island
Control Point
Flow
Flow
100' Pine
HP
50'
100' Fir
100' cedar
Top Bank
Waters Edge
164'
139'
Begins to flatten out in gradient
Mildly steep throughout
Flow
Flow
Flow
Waters Edge
Top Bank
100' cedar
HP
Cedar tree
Top of Bank
1' up from Bank
Waters Edge
Flow
Flow
Flow
Waters Edge
Top Bank
96' from Waters Edge
drop
75'
100' cedar
Hwy 126 Bridge

Appendix

2

Field Drawing

of

Leydig Meadow

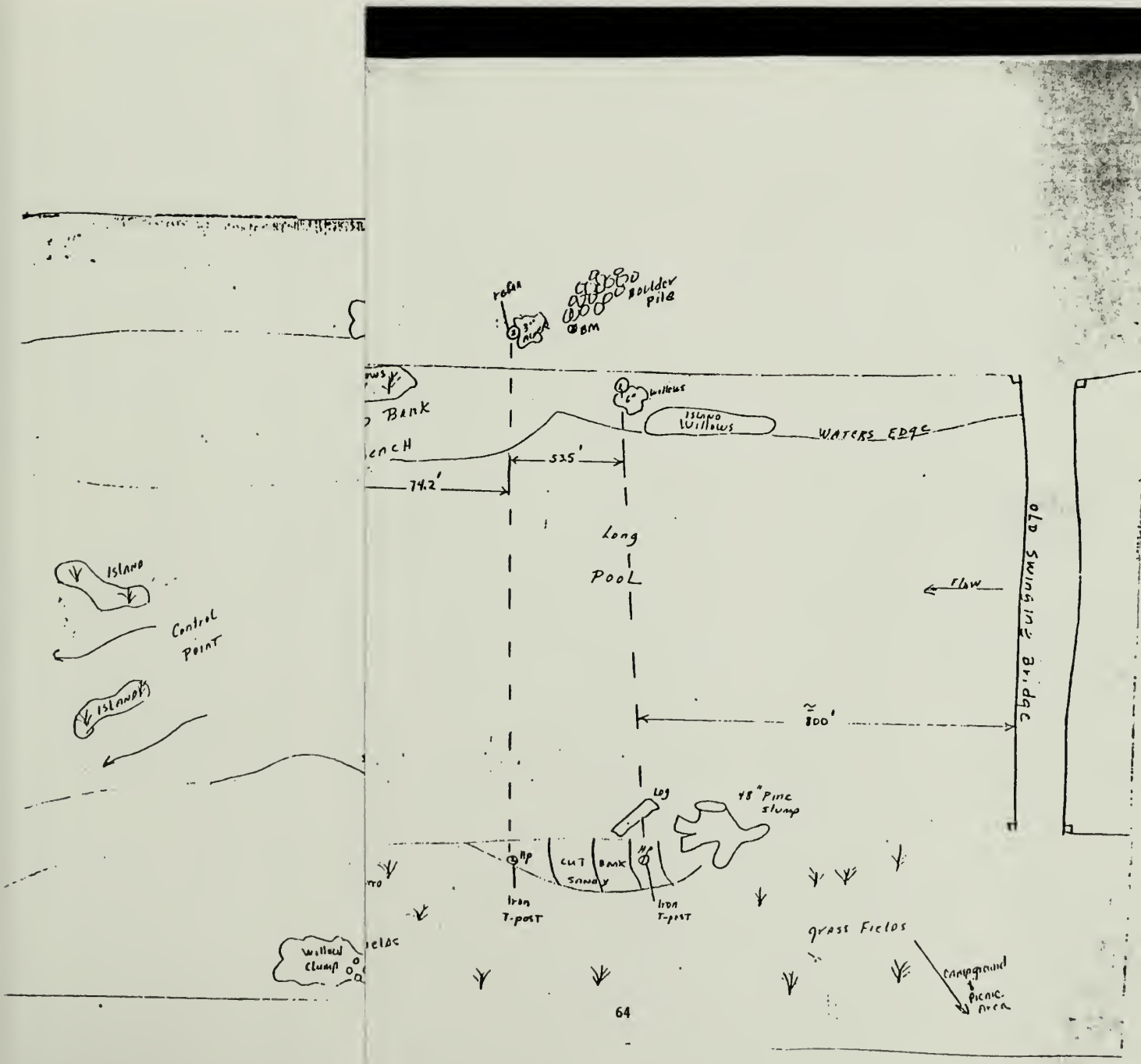
Study

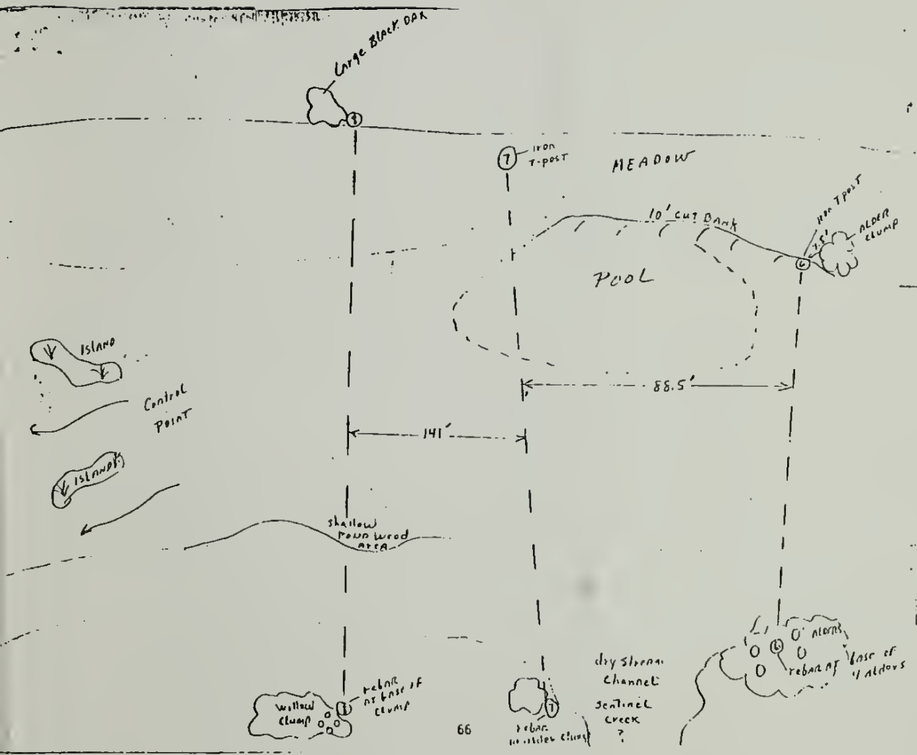
Site

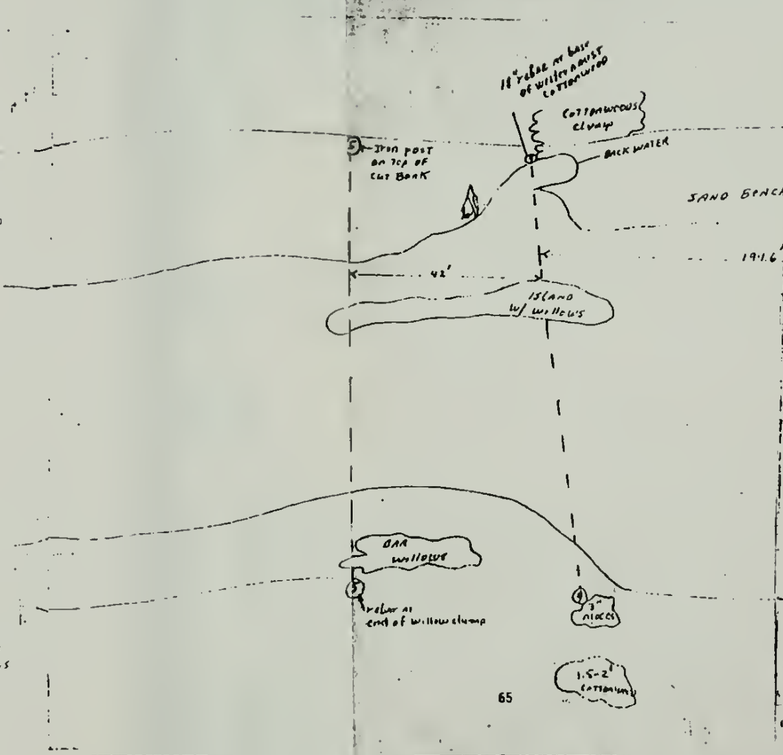
APPENDIX

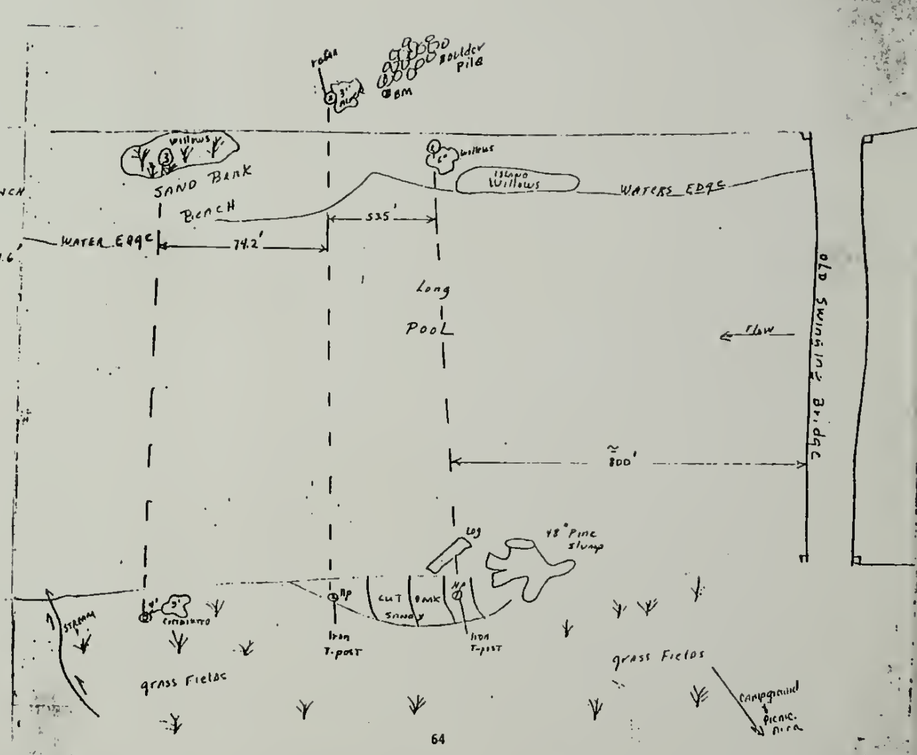
3

Merced River Instream Flow Study




Large Black Oak
1
Iron T-post
MEADOW
10' cut Bank
Iron T-post
Alder clump
POOL
88.5'
141'
Island
Central Point
Island
shallow Pond weed area
Willow clump
rebar at base of clump
rebar in willow clump
dry Stream Channel
Sentinel Creek ?
rebar at base of 4 alders
66


18" rebar at base of willow/ most cottonwood
Cottonwoods clump
Iron post on top of cut Bank
BACK WATER
SAND BENCH
191.6'
42'
Island w/ willows
BAR willows
rebar at end of willow clump
3" Alders
1.5-2' cottonwood
65


rebar
Boulder Pile
BM
Willows
SAND Bank
Bench
Willow
Island Willows
WATERS EDGE
WATER EDGE
74.2'
535'
Long
POOL
flow
Old Swinging Bridge
~800'
Log
48" Pine stump
Stream
3' cottonwood
BP
cut Bank Sandy
Iron T-post
Iron T-post
grass Fields
grass Fields
Campground & Picnic Area
64

APPENDIX

3

Merced River Instream Flow Study

Modified Wentworth

Substrate Evaluation Scale

Scale Value	Substrate Type	Approximate Size (mm)
1	Plant Detritus	-
2	Mud	-
3	Silt-Clay	.06
4	Sand	.06-2
5	Gravel	2-64
6	Rubble	64-500
7	Boulder	500-4000
8	Bedrock	4000+

Appendix

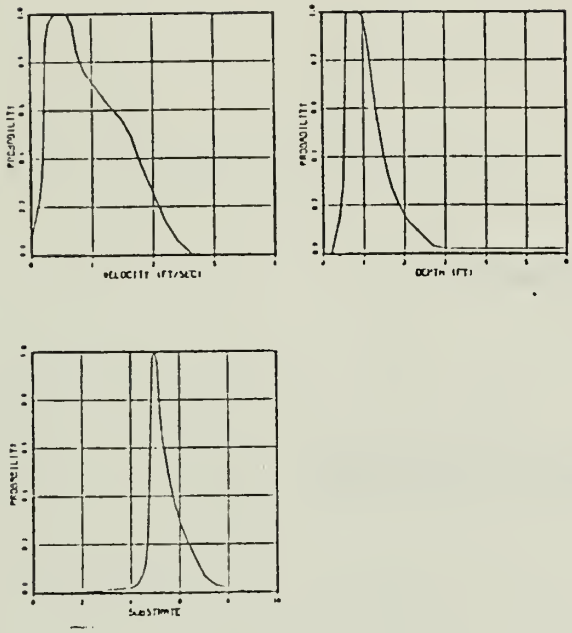
4

Rainbow Trout

Preference Curves

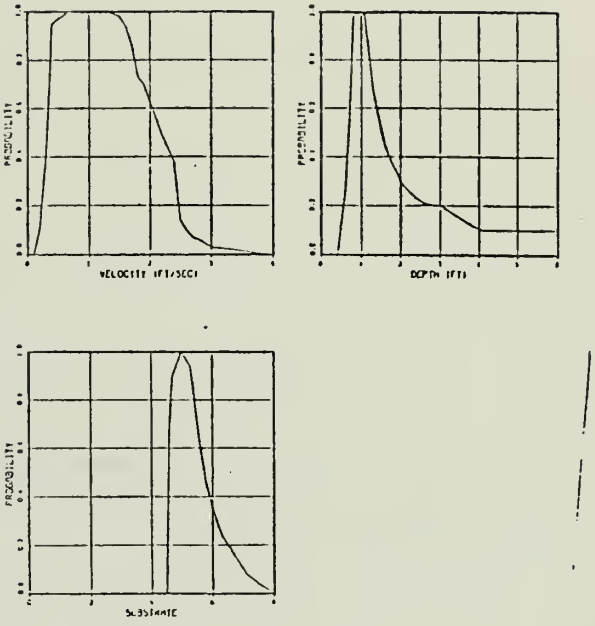
RAINBOW TROUT

11100 FRY 78/01/24.



RAINBOW TROUT

11101 JUVENILES 78/01/24.



RAINBOW TROUT

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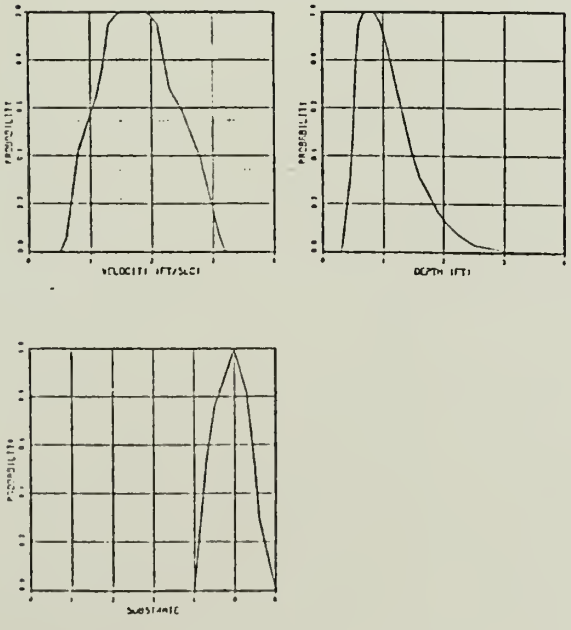
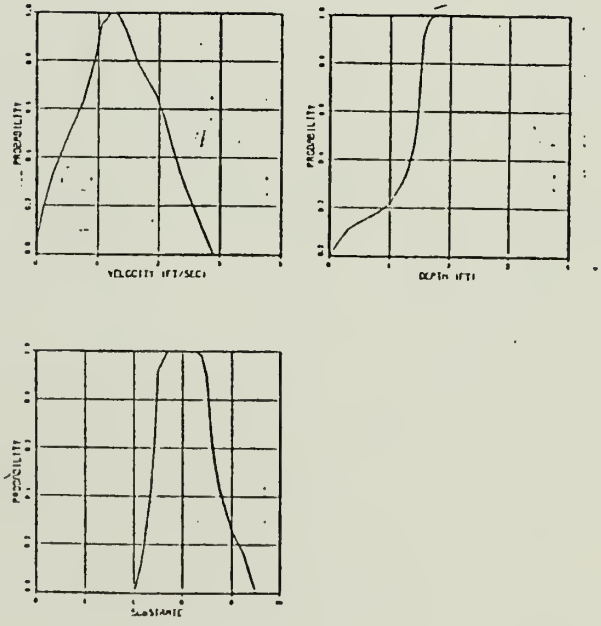


RAINBOW TROUT

11102 ADULT 78/01/24.



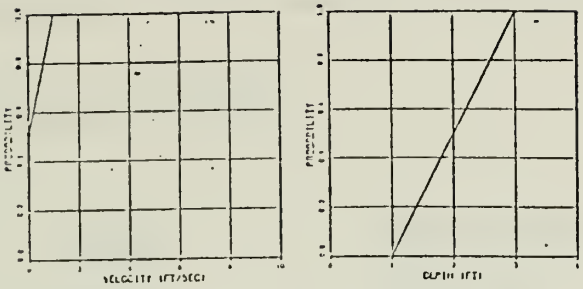
Appendix

5

Recreational Preference Curves

BOATING ROWING RAFTING DRIFTING

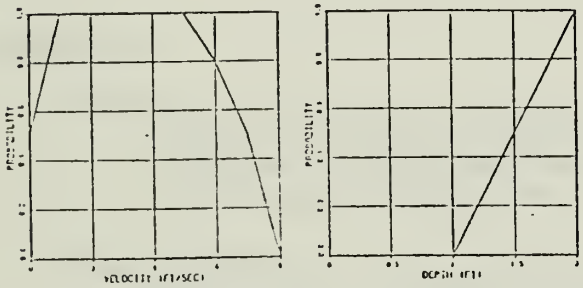
720400 78/06/26.



NOTE: Velocity plots have a maximum of 10 fps. The curve for the velocity for this activity is at a probability of 1.0 at 10 fps, a 0.5 probability at 12 fps, and a 0.0 probability at 14 fps.

BOATING TUBING FLOATING

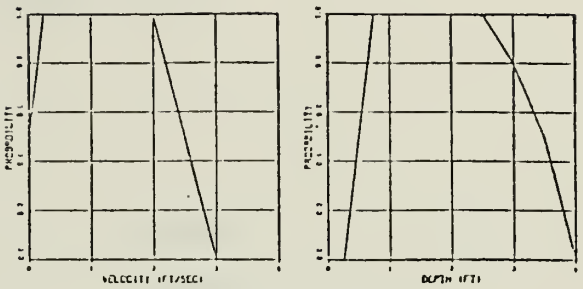
720500 78/06/26.



Preference for this activity is assumed to be independent of substrate type.

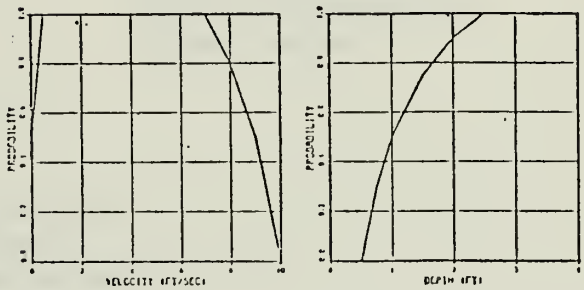
WATER CONTACT WADING

710100 78/06/26.



BOATING CANOEING KAYAKING

720300 78/06/26.



Preference for this activity is assumed to be independent of substrate type.

FISHING WADING

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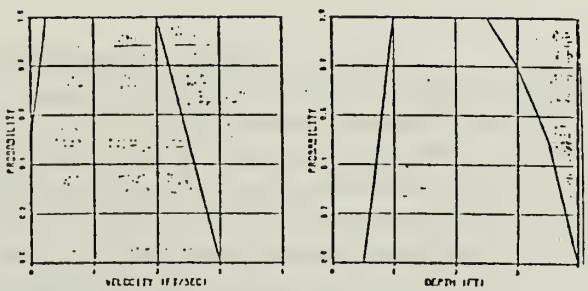
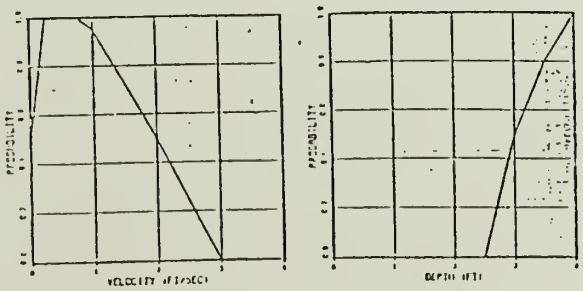


WATER CONTACT SWIMMING

710000 78/06/26.



Preference for this activity is assumed to be independent of substrate type.

Appendix 6. List of Available Recreational Preference Curves.

Recreation Activities

Fishing	Water Contact	Boating
Wading	Swimming	Sailing
Boat, power	Wading	Low power
Boat, nonpower	Water skiing	High power
		Canoeing-Kayaking
		Rowing-rafting-drifting
		Tubing-floating

Definitions

Fishing

Wading: fishing while walking in the stream.
Boat power: fishing from a power boat.
Boat nonpower: fishing from a nonpower boat.

Water Contact

Swimmming: propelling oneself through the water with no, or only occasional, contact with the bottom.
Wading: walking in the water, including water play.
Water skiing: being towed behind a boat on skiis.

Boating

Sailing: wind powered boating.
Low power: power boating, motor less than 50 horsepower.
High power: power boating, motor greater than 50 horsepower.
Canoeing-kayaking: using a canoe or kayak in a river.
Rowing-rafting-drifting: using a row boat, raft, or drift boat in a river.
Tubing-floating: floating on a device which is not a full-sized boat or raft. May include inner tubes, small rafts, air mattresses, etc. This activity is also a water contact activity. It is placed here for its similarity to rowing-rafting-drifting.

Appendix

7

Fish Population Sampling Data

for

Happy Isles

and

Leydig Meadow

Reaches

Fish Population Sampling - Multiple Pass/Removal Method (Happy Isles)

Stream: Merced River - Upper Reach - Below Happy Isles Bridge

Date: September 23, 1982

Crew Members: Gary Taylor, Rich Williams) USFWS; Anne O'Regan, Phil Tierney, Tom Ribe) NPS

Distance - Block Net to Block Net = 100 feet; stream width = 75 feet

Pass #1	Species	(cm) Length	(gms) Weight	Remarks
	Brown Trout	19.7	90	All fish taken showed
		17.8	65	good condition factor.
		10.2	20	Apparently good forage
		12.7	20	available.
	Rainbow Trout	19.1	75	Started @ 9:00 AM --
		19.1	70	had some problems with
		16.5	45	low conductivity; salt
		14.0	35	increased amps. from
		12.7	20	0.2 to 0.35.
		12.7	15	
		12.1	15	
		5.7	3	
		3.8	2	
Pass #2	Brown Trout	25.4	165	Good body condition in
		21.6	95	all fish taken.
		22.9	130	
	Rainbow Trout	24.1	140	
		20.3	95	
		16.5	35	
		11.4	30	
		14.0	35	

Fish Population Sampling - Multiple Pass/Removal Method (Leydig Meadow)

Stream: Merced River - Lower Reach - adjacent to Leydig Meadow

Date: October 14, 1982 @ 2:30 P.M.

Crew Members: Gary Taylor, Rich Williams (USFWS); Anne O'Regan, Phil Tierney, Tom Ribe (NPS)

Distance - Block Net to Block Net = 125 feet; stream width = 100 feet

Pass #1	Species	(cm) Length	(gms) Weight	Remarks
	Brown Trout	19.00	60	All fish taken showed
		18.00	37	good body condition;
		34.50	400	apparently no problem
		1.90	11	with food supply.
		1.80	5	
		1.80	7	
		1.85	4	Water temp. = 51°F
		1.85	3	
		1.85	4	D.O. = 10 ppm
		1.80	6	Pass Time = 25 min.
		1.70	6	
		1.70	5	
		1.80	4	This was the 3rd attempt
		1.85	6	to shock this
		1.75	4	section. On two other days
		1.7	4	we were rained out. On this
		1.8	5	day we were only able to com-
		1.8	5	plete one pass before it thundered and rained, and we had to cancel rest of work. This section was above and below Transects 1 and 2 approximately 800-900 feet below Old Swinging Bridge.

Appendix 8

Q vs. Available Habitat Area per 1000 Feet of Stream for Rainbow Trout
(Clear Water, S > .0026) at the Leydig Meadow Study Reach.

Q	FRY	JUVENILES	ADULT	SPAWNING
1.00	1030.09	9.95	249.18	0.00
5.00	4079.86	1429.35	1094.89	9.44
10.00	5847.57	4341.07	2154.35	1.86
20.00	6946.81	7528.45	4746.34	161.27
25.00	7024.80	8237.91	6132.97	352.20
30.00	7013.46	8664.77	6522.23	743.79
35.00	6877.83	9193.34	6396.21	1208.69
48.00	6680.68	10746.48	7893.40	2049.21
75.00	5607.00	12769.74	10953.40	2794.44
100.00	6783.98	13236.49	13869.33	3214.31
150.00	7651.48	13784.38	16824.13	4707.39
200.00	7394.85	14219.20	18122.07	5564.36
225.00	6741.88	14176.62	18558.78	5811.64
256.00	6820.80	13631.42	18944.13	6225.81
300.00	6728.27	13450.06	18977.73	6474.99
403.00	6464.68	12319.02	18941.56	7133.98
500.00	3528.17	8169.94	17360.17	6238.47
600.00	2439.58	5630.35	14994.00	4472.07

Q vs. Available Habitat Area per 1000 Feet of Stream for Rainbow Trout
(Clear Water, S > .0025) at the Happy Isles Study Reach.

Q	FRY	JUVENILES	ADULT	SPAWNING
1.00	195.72	36.58	385.14	0.00
3.00	836.87	496.57	938.76	9.23
5.00	1348.43	871.61	1321.13	28.11
10.00	2192.31	2009.46	2254.87	10.16
20.00	2768.47	3109.61	4813.77	1.52
35.00	2925.16	3195.83	6212.34	2.33
30.00	2702.67	3424.30	7608.30	3.13
36.00	2631.44	3624.22	9110.63	3.19
48.00	2497.78	3674.40	13007.07	2.63
75.00	2145.41	3484.91	17708.37	1.73
100.00	1876.61	3232.86	19124.53	1.33
150.00	1350.89	2616.12	19822.14	22.94
200.00	1067.86	2126.73	19566.53	32.00
256.00	963.63	1742.73	18835.66	15.16
403.00	676.86	1454.49	19193.21	1.26
600.00	529.69	1181.69	18369.86	0.00

Appendix

9

Recreational Area vs. Flow

Happy Isles Reach

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR WATER CONTACT - SWIMMING

MONTH	Q	01/21/03
1	2.00	27.72
2	5.00	219.15
3	10.00	1109.65
4	15.00	2414.03
5	20.00	4041.99
6	40.00	12769.90
7	75.00	19775.70
8	100.00	24467.79
9	150.00	30971.65
10	200.00	35451.72
11	256.00	38600.52
12	300.00	40436.15
13	403.00	42227.89
14	500.00	43075.61
15	600.00	43354.32

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR WATER CONTACT - SWIMMING

MONTH	Q	01/21/03
1	2.00	0.00
2	5.00	0.00
3	10.00	0.00
4	15.00	0.00
5	20.00	0.00
6	40.00	28.21
7	75.00	77.97
8	100.00	239.21
9	150.00	882.16
10	200.00	1918.67
11	256.00	2829.35
12	300.00	3280.51
13	403.00	4246.41
14	500.00	5011.62
15	600.00	7105.74

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR BOATING ROWING RAFTING DRIFTING

MONTH	Q	
1	2.00	15.86
2	5.00	109.09
3	10.00	530.33
4	15.00	1212.51
5	20.00	2032.97
6	40.00	6492.41
7	75.00	10782.37
8	100.00	14159.78
9	150.00	20652.55
10	200.00	24956.53
11	256.00	29511.95
12	300.00	32778.05
13	403.00	36654.90
14	500.00	40050.82
15	600.00	41840.35

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR BOATING CANOEING KAYAKING

MONTH	Q	
1	2.00	920.29
2	5.00	3375.73
3	10.00	6731.05
4	15.00	9694.07
5	20.00	11606.98
6	40.00	20141.65
7	75.00	29547.80
8	100.00	34734.32
9	150.00	35010.85
10	200.00	39406.38
11	256.00	42254.67
12	300.00	43572.90
13	403.00	46573.26
14	500.00	47765.81
15	600.00	48214.87

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR WATER CONTACT - WADING

MONTH	Q	01/21/03
1	2.00	6841.33
2	5.00	15610.15
3	10.00	19624.98
4	15.00	23420.66
5	20.00	26630.39
6	42.00	36031.50
7	75.00	39002.49
8	100.00	41110.35
9	150.00	38588.85
10	200.00	33480.42
11	256.00	32753.72
12	300.00	31106.45
13	403.00	28059.02
14	500.00	26975.04
15	600.00	24096.00

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR FISHING WADING

MONTH	Q	01/21/03
1	2.00	2001.45
2	5.00	7355.31
3	10.00	13053.91
4	15.00	18226.83
5	20.00	21375.49
6	40.00	31212.40
7	75.00	35726.51
8	100.00	37037.03
9	150.00	36279.11
10	200.00	34717.00
11	256.00	32356.63
12	300.00	31320.55
13	403.00	28007.72
14	500.00	27190.53
15	600.00	25515.52

Appendix

10

Recreational Area vs. Flow

Leydig Meadow Reach

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR WATER CONTACT - WADING

MONTH	Q	01/21/83
1	2.00	19956.71
2	5.00	32187.29
3	10.00	35443.71
4	15.00	37946.56
5	20.00	44291.13
6	40.00	56434.39
7	75.00	62760.77
8	100.00	69532.95
9	150.00	75279.41
10	200.00	76739.07
11	256.00	78247.43
12	300.00	79139.92
13	403.00	77770.84
14	500.00	71529.23
15	600.00	62217.77

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR FISHING WADING

MONTH	Q	01/21/83
1	2.00	15607.34
2	5.00	22760.62
3	10.00	30710.45
4	15.00	33536.62
5	20.00	38717.59
6	40.00	49380.61
7	75.00	55975.02
8	100.00	62569.53
9	150.00	70798.80
10	200.00	74911.07
11	256.00	76856.07
12	300.00	77426.53
13	403.00	78074.54
14	500.00	72549.64
15	600.00	62745.26

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR BOATING TUBING FLOATING

MONTH	Q	
1	2.00	3962.40
2	5.00	6931.37
3	10.00	11069.23
4	15.00	17099.18
5	20.00	18844.51
6	40.00	28220.44
7	75.00	33136.13
8	100.00	38626.42
9	150.00	42879.33
10	200.00	55920.37
11	256.00	63605.98
12	300.00	68853.39
13	403.00	78647.25
14	500.00	84202.20
15	600.00	90755.65

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR WATER CONTACT - SWIMMING

MONTH	Q	01/21/83
1	2.00	140.04
2	5.00	542.72
3	10.00	1002.44
4	15.00	916.35
5	20.00	1643.66
6	40.00	3072.92
7	75.00	6252.84
8	100.00	8743.19
9	150.00	12741.57
10	200.00	15480.35
11	256.00	17100.44
12	300.00	17604.84
13	403.00	17422.11
14	500.00	17185.42
15	600.00	10365.43

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR BOATING CANOEING KAYAKING

MONTH	Q	
1	2.00	8726.02
2	5.00	13098.69
3	10.00	18349.58
4	15.00	24751.06
5	20.00	26962.74
6	40.00	36530.49
7	75.00	44285.16
8	100.00	51031.87
9	150.00	61669.30
10	200.00	69074.23
11	256.00	75519.63
12	300.00	77522.27
13	403.00	59856.89
14	500.00	54515.16
15	600.00	57232.23

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR BOATING ROWING RAFTING DRIFTING

MONTH	Q	
1	2.00	2344.44
2	5.00	4111.76
3	10.00	6505.56
4	15.00	10204.00
5	20.00	11304.59
6	40.00	16875.75
7	75.00	23012.51
8	100.00	27976.62
9	150.00	36179.56
10	200.00	43290.48
11	256.00	49308.78
12	300.00	54170.38
13	403.00	62809.64
14	500.00	69533.15
15	600.00	74672.33

Appendix 11

Required Flows vs. Median Monthly Flows
for
Rainbow Trout

Period	Happy Isles				Leydig Meadow			
	Required	Normal	(1976) Dry	(1977) Critical	Required	Normal	(1976) Dry	(1977) Critical
Oct.	48	17*	118	30*	200	36*	211	40*
Nov.	48	27*	86	10*	200	52*	184*	21*
Dec.	48	43*	41*	4*	200	94*	94*	15*
Jan.	48	50	21*	7*	200	106*	57*	17*
Feb.	45	90	33*	14*	200	198*	79*	29*
Mar.	150	163	84*	25*	403	359*	196*	52*
Apr.	150	517	209	218	403	1030	385*	343*
May	150	1271	679	231	403	2370	911	379*
June	150	1210	169*	419	403	1763	236*	537
July	150	339	59	54	403	407	93*	69*
Aug.	46	64	29*	8*	150	94*	55*	15*
Sept.	48	20*	79	3*	200	36*	86*	7*

*Flows are less than required to provide maximum available rainbow trout habitat.